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EXPLORING CHATGPT'S IMPACT ON STUDENT-TEAM IDEATION OUTCOMES FOR NEW PRODUCT DEVELOPMENT: A PILOT STUDY

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ABSTRACT
Ideation techniques such as associative-thinking methods are commonly used to explore design proposals. However, limited experiences and knowledge in young designers can constrain diverse and meaningful design solutions. Emerging artificial-intelligence technologies, like ChatGPT, provide easy access to a global knowledge base which could inform associative-thinking outcomes. ChatGPT excels at generating lists of user-specified topics to accelerate learning with access to decades of gathered online experiences and insights. This study hypothesised that using ChatGPT to inform associative-thinking techniques would improve student idea generation compared to analogue methods in a new product development workshop. Product ideas were represented on Post-it notes, and outcomes were measured by fluency, flexibility, and originality. Thirty-five undergraduate students (first-year freshmen to fourth-year seniors) from Brigham Young University participated in two innovation workshops. One utilised ChatGPT in team ideation efforts, and the other used analogue methods. Over 75 percent of students had engineering related majors of study while less than 25 percent were non-engineering disciplines. All students were equally taught associative thinking techniques, and the ChatGPT group had additional training on software usage. Results show that fluency and flexibility outcomes were slightly lower in the ChatGPT group. In originality, the analogue group averaged twice the ideas of the ChatGPT group. Self-reported performance of flexibility and originality were lower in the ChatGPT group, but higher for fluency. Ideation effectiveness, enjoyment, and empowerment were all lower in the ChatGPT group. Observations revealed that ChatGPT-assisted teams had increased team interactions. Future research might benefit from longer ideation sessions and visualisation training.

Keywords: Product design education, associative thinking, design process, generative AI

1 INTRODUCTION
In the early stages of product design, ideation techniques such as associative thinking methods are commonly used to explore design proposals within a target problem space [1], [2]. Associative thinking connects ideas, words, or experiences across different areas of knowledge, industries, or geographies [1]. This can be done spontaneously as "free association" by connecting random ideas together to make a new solution to a design problem or, strategically as "goal-directed association" by connecting related ideas with a specific goal in mind [2]. This process may be constrained by a young designer's limited experience and knowledge, thus restricting the ability to generate diverse and meaningful design proposals compared to experienced designers.
ChatGPT technology provides easy access to a global knowledge base and experiences that potentially inform associative thinking outcomes [3], [4]. ChatGPT's simple conversational interface excels at quickly generating lists of user-specified topics beyond the speeds humans can generate. This technology accelerates learning by providing access to decades of gathered online experiences and insights [3], [4], potentially allowing design students to generate idea content, and judge quality and appropriateness [5], [6]—a capability that artificial intelligence tools struggle to achieve [7].
This study explores ChatGPT's impact on students' new product ideation outcomes from two design workshops utilising two associative thinking techniques. One workshop utilises traditional analogue methods, and the other incorporates ChatGPT into the workflow. We expected that inexperienced design students incorporating ChatGPT into their ideation workflow would improve their ideation outcomes by

utilising ChatGPT's abilities to (1) quickly produce lists of relevant subject-matter topics for new idea generation and (2) provide access to unfamiliar knowledge or topics.
To assess ideation outcomes, methods from Divergent Thinking tests were used to measure: (1) fluency, the number of ideas generated by each student; (2) flexibility, the diversity of idea categories proposed; and (3) originality, the number of novel, unexpected, or unique ideas within the relevant context of the idea [8]. Given the subjective nature of ideation evaluation, techniques from the Consensual Assessment Technique (CAT) to appraise ideation outcomes were employed [8]. A post-workshop survey gauging participant perception of the study experience was administered to help interpret quantitative and qualitative results.

2 METHOD

A pilot study was conducted with two sections of a product development class, taught at Brigham Young University (BYU). The class occurs several times each semester and takes place during a single seven-hour day. Data was collected from classes taught one week apart. Students worked together throughout the day, learning and practising design exercises and techniques, such as SCAMPER, associative thinking, 5-whys, and mind mapping, to design new product proposals for self-identified product problems [9].
Free and goal-directed associative thinking were taught to both classes and selected as vehicles to explore the impact of analogue ideation versus technology-assisted ideation. Classroom instruction is performed in real-time by an instructor; however, for the associative thinking segment of the class, students viewed videos explaining associative thinking techniques, ensuring consistency across both classes. The class utilising ChatGPT (version 3.5) had additional video instruction demonstrating how ChatGPT could assist with free and goal-directed association techniques and a computer workstation to facilitate ChatGPT explorations. Each team's ChatGPT session was displayed on a wall-mounted television, allowing students to contribute questions or prompts and see live ChatGPT output.

2.1 Participants

Thirty-five students participated in the study. Sixteen students (4 teams of 4 students each) participated in the class focused on analogue ideation. Nineteen students (3 teams of 5 students and 1 team of 4 students) participated in the ChatGPT-assisted class. Approximately 75 percent of participants were manufacturing, mechanical, or technology engineering students while 25 percent of participants were students outside of the engineering college (e.g., accounting, communications, cybersecurity, human development, or physics). All participants were undergraduate students ranging from freshmen (first year) to seniors (fourth year). Participants received no extra credit or compensation.

2.2 Study Procedure

2.2.1 Analogue Ideation Group

Participants in the analogue-ideation class were taught associative thinking approaches for ideation through an instructional 2.5-minute video about free-associative thinking. Next, they were instructed to collaborate with their team to generate as many ideas as possible for their design problem using techniques described in the video. Participants used markers and Post-it notes to document ideas using sketches and text descriptions with enough detail so that someone unfamiliar with their problem could understand the concept. Participants had 8 minutes to ideate and document their ideas; at the end of the ideation session, each team's Post-it notes were collected. Immediately following the collection of ideas, a second 2.5-minute video about goal-directed association was presented, and participants were again instructed to generate as many ideas as possible in 8 minutes using the techniques described. Post-it notes were collected at the end of that session, and the class proceeded to the next course topic. At the workshop's conclusion, students were asked to complete a 9-question survey about their associative thinking experience from the class.

2.2.2 ChatGPT-assisted Ideation Group

Participants in the ChatGPT-assisted class followed the same procedures as the analogue-ideation class; however, two additional 1.5-minute videos of ChatGPT instruction and demonstration for free and goal-directed associative thinking were presented. The video demonstration for free association showed how ChatGPT could generate a list of random words and explore associations and connections about ideas or concepts related to a hypothetical design problem. The goal-directed associative-thinking video

demonstrated how to use ChatGPT to explore new associations and unfamiliar ideas through question-and-answer chat prompts similar to a conversation with a subject-matter expert for the same hypothetical problem. Participants in the ChatGPT session also generated as many ideas as possible in their teams, documented them on Post-it notes, and collected them after the ideation sessions. Students were asked to complete the same post-workshop survey at the end of the day.

2.3 Synthesis

2.3.1 Ideation Outcomes

Both groups' ideas were sorted and assessed by two instructors who teach new product development classes and categorised the outcomes. Fluency was measured by quantifying the number of total ideas generated by each team. Unclear and incomplete ideas were eliminated from the study results. Flexibility was measured by categorising each team's ideas through affinity mapping and quantifying the resulting idea groups [10]. Originality was measured by quantifying the number of novel, unexpected, or unique ideas not commonly used in the relevant domain.

Each team had different colour Post-it notes, easily distinguishing separate team outcomes. An example of organised and quantified ideation outcomes are shown below in Figure 1.

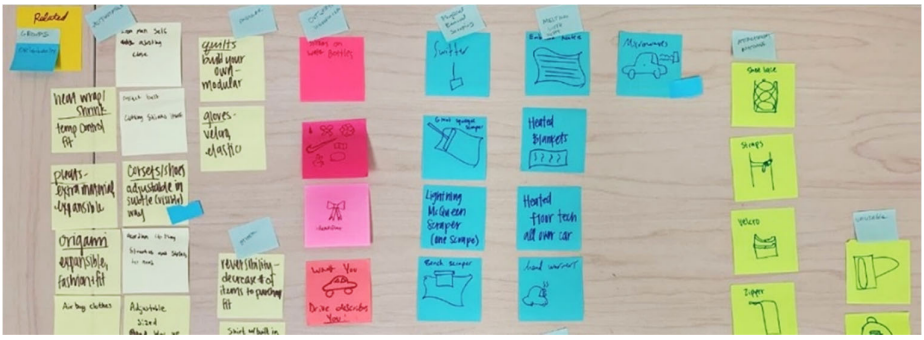

Figure 1. Affinity mapping of ideation outcomes: fluency, flexibility, and originality

2.3.2 Post-workshop Survey

An internet-based survey was administered to participants at the conclusion of the class. Questions gathered insights into participants' self-perception of the effectiveness of analogue or ChatGPT-assisted associative thinking using a Likert rating scale from 1-5. Questions 1 and 2 asked about the perceived effectiveness (i.e., 1 = not effective, 5 = very effective) of free and goal-directed associative thinking. Question 3 explored fluency by asking how often the student felt "stuck" when generating ideas for their design (i.e., 1 = often stuck and 5 = rarely stuck). Question 4 uncovered how original they thought their team's ideas were (i.e., 1 = not original to 5 = very original). Question 5 asked how diverse (flexibility) their ideas were (i.e., 1 = not diverse to 5 = very diverse). Questions 6 and 7 asked how enjoyable and empowering associative thinking was for their teams. In the ChatGPT group, the wording asked how enjoyable and empowering using ChatGPT was to aid associative thinking (i.e., 1=not enjoyable/empowering to 5 = very enjoyable/empowering).

The participants' discipline and team designation were also gathered. The survey took, on average, less than five minutes to complete.

2.3.3 ChatGPT Prompt Analysis

Incorporating ChatGPT into the ideation process was a new experience, and exploring its utilisation was important. Student-generated input prompts were saved and analysed thematically to observe student interaction use. Prompts were categorised by type and quantified.

3 DATA ANALYSIS AND RESULTS

3.1 Ideation Outcomes

The quantifiable data from the two classes for ideation outcomes, post-workshop experience surveys, and ChatGPT conversations are outlined below.

Table 1 summarises the total fluency, flexibility, and originality results for all teams for each class. Ideation outcomes have been calculated per student because of differing class sizes between the analogue-ideation class (n = 16) and the ChatGPT-assisted class (n = 19).

Table 1. Ideation outcomes for associative thinking idea generation

Class	Fluency (ideas per student)	Flexibility (idea groups per student)	Originality (original ideas per student)
Analogue (n = 16)	5.6	2.8	0.8
ChatGPT (n = 19)	5.1	2.6	0.4

3.2 Post-workshop Survey

The post-workshop survey was completed by 30 of 35 students attending as it was not a mandatory requirement of the course. Results for self-perception of fluency, flexibility, originality, and overall effectiveness for free and goal-directed associative thinking from both classes are shown in Table 2. Results are reported on a scale from 1 (lowest) to 5 (highest).

Table 2. Self-perceived ideation outcomes and associative thinking effectiveness

Class	Fluency Rating	Flexibility Rating	Originality Rating	Effectiveness of Free-Associative Thinking Rating	Effectiveness of Goal-Directed Associative Thinking Rating
Analogue (n = 15)	3.3	4.1	3.9	4.1	3.9
ChatGPT (n = 15)	3.7	3.5	3.4	3.7	3.5

The post-workshop survey results for self-perception of enjoyment and empowerment of associative thinking activities are shown in Table 3 on a scale from 1 (lowest) to 5 (highest).

Table 3. Self-perceived enjoyment and empowerment rating in associative thinking activities

Class	Enjoyment Rating	Empowerment Rating
Analogue (n = 15)	4.4	4.2
ChatGPT (n = 15)	3.9	3.7

3.3 ChatGPT Prompt Analysis

Participant ChatGPT prompts were individually assessed and coded into categories of: (1) “unknown knowledge questions,” (2) “analogous concept exploration,” (3) “random words,” (4) “previous output elaboration,” and (5) “solve my problem.” Table 4 presents the summary of prompt types by quantity and frequency percentage.

Table 4. ChatGPT prompt type, count, and frequency percentage

Prompt Type	Prompt Count, Frequency (%)
Unknown Knowledge Questions: “Can zippers be waterproof?”	22, (37%)
Analogous Concept Exploration: “Tell me some unique ways to store food on the go”	20, (33%)
Random Words: “Create a list of random objects”	9, (15%)
Previous Output Elaboration: “What are more ideas around item #8”	6, (10%)
Solve My Problem: “Create 'adaptive technology' for removing ice from a windshield”	3, (5%)

4 DISCUSSIONS

4.1 Ideation Outcomes

Ideation outcome results summarised in Table 1 show evidence that ChatGPT-assisted ideation yields slightly lower fluency, flexibility, and originality outcomes than for analogue ideation. Comparatively, fluency and flexibility outcomes were only slightly lower in the ChatGPT-assisted class; however, the originality outcome was larger. Students in the analogue-ideation class produced, on average, twice the number of original ideas compared to students in the ChatGPT-assisted class.

4.2 Post-workshop Survey

Results summarising self-perceived ideation outcomes in Table 2 indicate that fluency was perceived as higher, while flexibility and originality were perceived as lower in the ChatGPT group compared to the analogue group. Even though the ChatGPT-assisted group produced fewer ideas per student, they reported a higher perception in fluency. One possible reason for this result comes from anecdotal observations of the two classes. The ChatGPT-assisted class engaged in more team discussion, design exploration, and new knowledge investigation compared to the analogue class. It's plausible that ChatGPT output (i.e., lists of related ideas, topics, and expert knowledge surrounding a design problem) stimulated more verbal idea explorations and conversations in a team environment. The time spent searching for an optimal design solution through engaged team discussions may have taken precedence over using time and effort to document interim ideas. Conversely, students in the analogue-ideation class rated their team's ideas with higher diversity (flexibility), originality, and free and goal-directed associative thinking effectiveness than the ChatGPT-assisted group. This may be attributed to students having a stronger sense of self-efficacy and ownership of their own ideation efforts compared to technology-assisted efforts. Additionally, students in the analogue-ideation class may have a clearer understanding of how their own design ideas may emerge or be developed. In contrast, the ChatGPT-assisted design ideas may seem less familiar to students as these ideas may come from domains where students have less knowledge and experience.

The enjoyment and empowerment ratings, as shown in Table 3, indicate that ideation activities in a team environment without ChatGPT have higher enjoyment levels compared to using ChatGPT. This result seems contradictory to anecdotal observations of higher student engagement among team members but may be a result of other factors such as the additional task of using a computer together as a team instead of just using team members alone without ChatGPT.

4.3 ChatGPT Prompt Analysis

Results from the ChatGPT prompts, as shown in Table 4, support the notion that ChatGPT can be used as a tool to inform inexperienced design students in ideation activities. The most common prompt type (1 out of 2.5 prompts) was the "unknown knowledge questions" prompt. These are prompts used to gain more information or learn about unknown topics. These prompts demonstrate that students investigated idea content unfamiliar to them. The second most common prompt type (1 out of 3 prompts) was the "analogous concept exploration" prompt, providing ideas specific to the prompt topic. "Random words" were used approximately 2 times per team (1 out of 6.5 prompts) in practising the free-associative thinking activity. One out of ten prompts were "previous output elaboration" prompts used to elaborate on previous conversation output, demonstrating the utility of a conversation-like interface for design explorations. Lastly, only three prompts were "solve my problem" prompts. These prompts explore more complex and solution-specific ideas related directly to a design problem. These types of prompts reflect a student's intent to have ChatGPT directly generate associative thinking connections rather than having it produce lists of topics that the students must associate on their own. There were 60 prompts in total for the two ideation sessions, averaging 8 prompts per team for each 8-minute session. Therefore, on average, students input prompts into ChatGPT at a rate of approximately one prompt per minute.

4.4 Limitations

Introducing a new technology-assisted ideation method into an existing course curriculum, rather than a stand-alone experimental study, limited the time available for ideation activities. Gathering data within a classroom setting offers valuable real-world perspectives; however, conducting longer ideation sessions could enhance ChatGPT's effectiveness in idea generation. It is possible that two 8-minute sessions may not fully exhaust a student's design ideas, while a longer session could better showcase the impact of using ChatGPT on ideation outcomes compared to analogue ideation.

The class does not focus on teaching rapid design communication, yet assessing ideation heavily relies on clear design communication. As student ideas were collected and evaluated for ideation outcomes, it was evident that some students articulated design concepts more effectively than others who lacked clear design communication skills. This may be attributed to student experience and training in visual communication based on their disciplinary pedagogical norms. Since unclear or incomplete ideas were excluded from the study results, for future studies it is important that ideas are properly conveyed to avoid being disregarded due to ambiguity or confusion. Even though less than seven percent of student

ideas were excluded because of unclear or incomplete designs, the overall communication of ideas should be improved for a study like this that relies heavily on clear communication.

4.5 Future Work

Future research allocating more time for extended ideation sessions may prove more effective in enhancing creativity outcomes for ChatGPT-assisted idea generation. Previous studies on creativity utilising ChatGPT conducted ideation sessions averaging 30 minutes [4], which demonstrated improvements in individual creativity outcomes.

Additional research should include training to improve rapid idea communication with sketching, text description, and visualisation practice. Performance differences between disciplinary backgrounds and skills in visual and written communication should be addressed. Alternatively, advances in artificial intelligence for image generation from text descriptions might prove useful to bridge the gap between inexperienced visualizers and clear ideation communication.

While anecdotal observations of higher engagement with ChatGPT-assisted student teams were insightful in this pilot study, subsequent studies could benefit from implementing in-class video recordings to capture student behaviours that would further validate the anecdotal observations of higher team engagement with using ChatGPT.

5 CONCLUSIONS

ChatGPT was predicted to improve ideation outcomes because of its ability to rapidly generate topical lists and provide insight to inexperienced students; however, initial results of this study do not confirm this prediction. For short-duration ideation sessions and limited experience with ChatGPT, it may not be useful to incorporate in the ideation process if maximising ideation outcomes is the desired result. However, ChatGPT technology shows promise for improving student engagement and assisting inexperienced students in knowledge exploration. Given more ideation time, ChatGPT may impact idea generation and associative thinking, serving as a valuable tool to complement traditional analogue ideation methods among designers.

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